ReDecay, a method to re-use the underlying events to speed up the simulation in LHCb

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Introduction

- For LHCb upgrade will need to simulate more complex events and in a bigger amount
- Time for simulation [M. Clemencic et al. 2011 Phys. Conf. Ser. 331 032023] completely dominated by detector transport (O(95%–99%))
- Increased CPU resources and new Geant versions will not suffice
- Existing fast simulation options in LHCb:
  - Customize used subdetectors to the analyst's needs
  - Only simulate the exclusive final state of interest (O(95%–99%) CPU time reduction)
  - Currently in development: shower libraries for the calorimeters and fully parametric description

  - See also 'Fast simulations in LHCb' talk in N-14, Tue October 24 at 1:30 pm.

  - Motivation
    - Many LHCb analyses involve exclusive decays, e.g. $D^+ \rightarrow K^-\pi^+$ relevant quantities from decay products, not from the rest of the event
    - Simulating only signal decay products already implemented significant discrepancies with data: higher efficiencies and better resolutions caused by much lower detector occupancy due to missing underlying event
    - Solution: do not remove the underlying event but re-use it several times

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  - Impact
    - Events are not independent but correlation depends on studied variable:
      - No problem for child track variables (e.g. $p(K^-)$)
      - Large problem for global event variables (e.g. number of PVs)
      - Sample with replacement (bootstrapping)

  - Challenge: Statistical uncertainty

  - Naive $\sqrt{N}$
    - Keep underlying event
    - Make multiple new signals with:
      - Same parent momentum
      - New decay vertex
      - New final state kinematics
    - Merge signal and underlying event before the digitisation step: final events are indistinguishable from nominally simulated ones

  - Bootstrapped

  - Simulated events

  - CPU work

ReDecay benefits

- Independent of used generator
- Automatically benefits from general improvements to the LHCb detector simulation
- Compatible with other fast simulation options (e.g. shower libraries)
- Same precision on simulated detector response (by construction)

- 10—50 times faster than nominal full simulation

Signal only vs ReDecay: $D^+ \rightarrow K^-\pi^+$ reconstruction efficiency

- Signal only discrepancies in the efficiencies with respect to nominal simulation vanish for ReDecay

- Estimated CPU resources needed by LHCb with different simulation options

- Simulation vanish for ReDecay

- Signal only discrepancies in the efficiencies with respect to nominal

- Large increase in number of events that can be produced with same amount of CPU resources
- Very beneficial for extracting multi-dimensional efficiencies as a function of final state quantities
- Correlations between events are found to be negligible
- An example: phase-space variables for $D^+ \rightarrow K^-\pi^+$ sufficient

- Impact

- Pledgeable
- Sim at 100% of data
- FastSim at 100% of data
- Sim at 50% of data

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